25X1

Approved For Release 2004/11/30 : CIA-RDP78B04770A000200020022-5

PROPOSAL

DEVELOPMENT

OF AN

AUTOMATIC TARGET RECOGNITION SYSTEM

[redacted] 25X1

Prepared by:

[redacted] 25X1

Approved For Release 2004/11/30 : CIA-RDP78B04770A000200020022-5

FOREWORD

This unsolicited technical proposal is submitted by [redacted] 25X1
25X1 [redacted] This proposal, [redacted] TP-288, 25X1
describes a two-year research and development program which will, at its completion, yield an operational prototype of an adaptive, automatic, target-recognition system.

Phase I of the two-phase program will be a combined research, investigation, and experimental program devised to establish the basic design parameters and the related performance characteristics of the operational system. Phase II will be devoted to the detailed design, construction, and testing of the prototype system.

25X1 [redacted] a prime contractor in the areas of research, development, and fabrication, works within the realm of the physical sciences to originate new concepts and improve existing techniques in military weapon and countermeasure development. Military electronics and electro-mechanical
25X1 equipment are [redacted] major products.

Although the Company is qualified for operation in the
25X1 small business category, [redacted] reputation in the research and development field has been gained in the fulfillment of contracts that were acquired competitively and were awarded
25X1 solely on the basis of [redacted] technical originality and excellence.

The Company is located at [redacted] only a few minutes from Washington, D. C. Research efforts are greatly facilitated by proximity to both ASTIA and the Library of Congress. 25X1

25X1 [redacted] occupies a functionally designed facility with 40,000 square feet of floor space. Engineering offices and laboratories, and fully equipped model, prototype, and fabrication shops are contained within the building's six bays.

25X1 [redacted] employs approximately 200 persons, of whom more than fifty percent are professional and other technical personnel. The Company's organizational structure expedites the carrying-out of difficult technical assignments by minimizing administrative detail and by providing the best available engineering support services.

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I. INTRODUCTION AND SUMMARY

In the past several years, a number of investigations have been made of the problem of automatic pattern-recognition. One of the more difficult tasks to be accomplished in this field, one in which the patterns to be recognized are in the form of optical images, is that of automatically identifying targets on aerial photography. Limited forms of image processing and subsequent adaptive recognition processes have, to this point, produced encouraging results.

The dual tasks of the proposed program are: (1) evaluate the techniques previously explored to establish which forms of processing can be most successfully used and (2) make use of state-of-the-art hardware techniques in the design and construction of an adaptive, automatic target-recognition system.

The general approach to all problems of this kind involves accomplishing two major tasks: (1) extracting measurements from a data source characterizing the patterns, and (2) building a statistical model of each of the classes of interest based on these measurements. Data from new patterns can then be compared with the stored models, and, if the similarity is within prescribed limits, a classification can be made.

Data sources such as aerial imagery have presented a formidable problem since the total information content for typical scenes is extremely high. At a resolution of twenty lines per millimeter, it is possible to define 40,000 discrete resolution elements in one square centimeter of an aerial photograph.

Because this number is larger by several orders of magnitude than the number of measurements that can be dealt with by conventional pattern-recognition methods, fewer measurements must be supplied to the system. In part, reducing the number of measurements supplied to an adaptive recognition system is justified by the fact that images under translation and rotation keep the same classification. In successfully implementing automatic recognition, it is essential to define which measures both efficiently characterize the imagery and display minimum sensitivity to image variables such as translation and rotation.

Once the appropriate set of measurements has been made, a relatively straightforward adaptive-learning process can be used to construct the class models, using measurements from examples of each class. The process consists of accumulating and comparing data from all examples, setting the appropriate limits of variation which can be expected and setting up special subclasses in classes which have more than one basic mode of input.

We may summarize the basic approach by the simple model shown in Figure 1. The input or data source (which may be film) is scanned, and the video data is supplied to a special electronic processing system. In the processor, the video data is

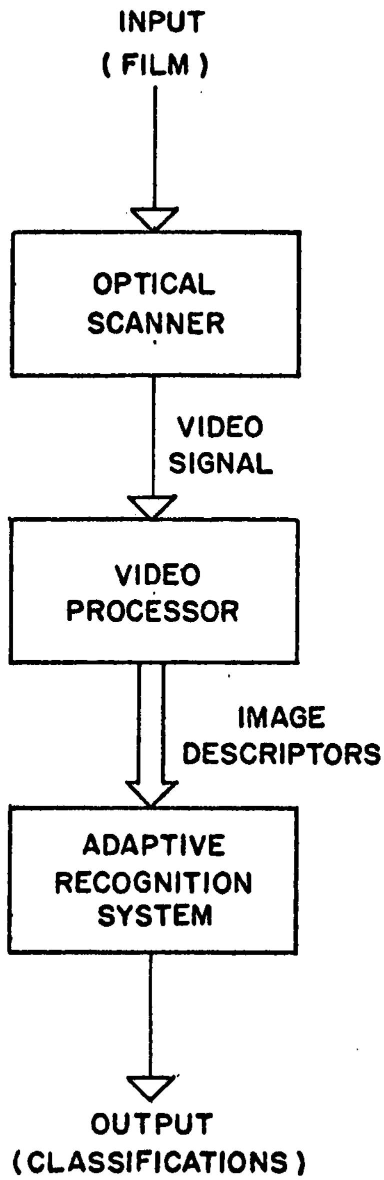

FIGURE 1

AUTOMATIC TARGET-RECOGNITION MODEL

transformed into a significantly smaller number of measurements describing the imagery. The adaptive recognition system will provide, once it is trained with measurements made on suitable examples of classes of imagery, the required classification data on new inputs.

The diverse methods of scanning, processing, and recognizing the aerial imagery will be evaluated during the design effort of the first phase of this program. The data resulting from programs under current sponsorship, as well as from a number of previous programs carried out at [redacted] will serve 25X1
as the data base for this study. [redacted] has carried 25X1
out studies on pattern recognition and wideband video-signal recognition under the following contracts:

25X1

[redacted]

CONFLEX I, a large capacity, conditioned-reflex system, was constructed under the second of these contracts. Our investigations of automatic target recognition on aerial photography have been carried out under the following contracts:

25X1

[redacted]

These contracts have been devoted primarily to testing the capabilities of the CONFLEX system and the use of preprocessing methods for measuring properties of imagery which are not sensitive to translation and rotation. The first phase of research

will also draw upon the investigations carried out at other 25X1
laboratories, [redacted] 25X1

The combined results of our programs and those of others will be used to full advantage in insuring a practical and successful approach to the design of the operational system. Sufficient experimental work will be included in the first phase to remove any doubts regarding the essential performance characteristics of portions of the system.

In the paragraphs which follow, some of the important facets of research and development associated with each basic subsystem will be discussed. Finally, a detailed program will be laid out showing the areas of concentrated effort for both phases of the program.

II. RESEARCH AND DEVELOPMENT CONSIDERATIONS

A. THE OPTICAL SCANNER

The optical scanner will reduce input data into the form used by the processor, and the data will be transduced onto various roll film formats. At least two forms of optical scanning will be considered for use in the operational system -- a conventional TV raster scan and the line-integral scans under current study.

A typical point-by-point raster scan of pictorial data clearly supplies all of the information necessary to describe the scene under process. Were this the only consideration, the conventional TV scan would suffice in accomplishing the initial data pickup. We must look ahead, however, and realize that measurements of picture information must be through the summation of appropriate combinations of individual picture elements. This summation may be accomplished in several ways, using the conventional TV scan.

In one case, we may buffer the point-scan information on the entire scene and, through serial or parallel processing, effect the necessary weighted combinations necessary for measuring the pictured information. At the other extreme, we may choose to operate directly upon the input image, using optical spatial filtering or area-matching masks to detect various measurements. In what might be termed an intermediate form of transducing process, the scene can be scanned with a multipoint scan having sample apertures arranged to sum image activity over limited areas. The line-integral scan is one form of multipoint scan that will be of interest here.

Edge enhancement is the simplest means of processing point-scan data. Here, an electronic filter with known impulse response recombines local picture elements to generate a new video signal. A high-pass filter will produce a new video signal which carries information principally on the edges of images where abrupt changes in contrast take place. The time-sequence weighting of point-scan data in this manner does not permit the simple union of adjacent data points which are not oriented in the direction of scan. Thus, a conventional TV scan will permit edge enhancement for one orientation only. Various forms of isotropic scans and rotating TV rasters have been used to circumvent the direction sensitivity of simple point-scan processes.

Although the optical scanner will be a physically separate operating unit, the design of this unit will strongly depend upon the video processing methods selected for use in the system. Since the literature on the more common forms of point scanning is relatively abundant, no further details of their structure will be given here. Their applicability will be discussed in the next section on video processing. Line-integral scanning will prove to be of interest, and a brief discussion of this scanning method is included. The reader is referred to the final report prepared by [redacted] 25X1

25X1 under [redacted] for details concerning the development of the integral scanning system described here.

Figure 2 shows a schematic view of a line-integral scanning process. Backlighted sample slits are positioned at regular intervals around a cylinder, and, in the center of the cylinder, a 45-degree rotating mirror directs the light from successive slits through the objective lens. An image of each slit is thereby swept across the photographic transparency under process. Each successive sample slit is rotated by an amount equal to its angular separation on the sample slit cylinder. A condensing lens collects the light and focuses it onto a multiplier phototube which transduces the light signal. The video waveform obtained is a series of video pulses; each pulse is made up of the series of line integrals sampled as the slit sweeps across the picture. The simple implementation shown here can be replaced with flying spot or vidicon hardware with appropriately programmed scans.

When a line-integral scan is used, a portion of the image combining process is carried out quite easily in the initial stage of processing. Further advantages of this form of scan will be discussed in the next section.

In addition to the constraints imposed on the optical transducer by the form of processing selected, the format of the incoming data must be considered. It is anticipated that the input will be rolls of aerial film ranging from five to nine inches in width. Our scanning process must accommodate these formats and maintain a reasonably fast processing rate. A system is envisioned in which the roll film is in continuous motion, providing a coarse x-scan while an oscillating or rotating mirror(s) sweeps the center of attention back and forth across the film in the y direction.

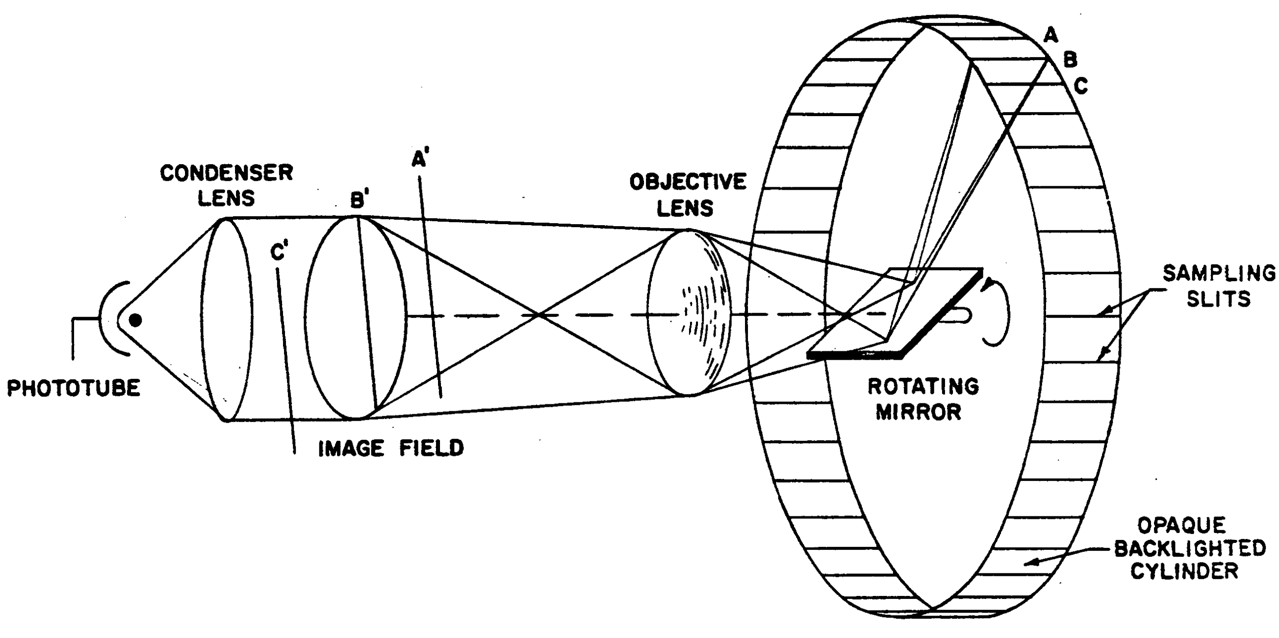

FIGURE 2

IMPLEMENTATION OF SUCCESSIVE INTEGRAL SCANS

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An optical system for integral scanning, as shown in Figure 2, would perhaps be employed in conjugate form. An image of the scene under process would be brought via the coarse scan mirror just described to the rapidly rotating mirror required for producing the video signals. Phototubes behind each of the sampling slits (or an optically abbreviated equivalent) could be used to generate the line-integral scan data as the image sweeps by. In such an implementation, there is available around the sample cylinder a moving image which makes one full rotation as it sweeps around the cylinder. If a sample slit is replaced with a small aperture, then a point scan can be had which scans in any desired direction on the field.

The film transport system required will be quite simple. The usual loose coupling drive will be provided for feed and take-up spools while the film speed is governed by friction drive on the film itself. It may prove desirable to sense the interframe spacings for purposes of frame count and to inhibit attempts to classify the severed imagery. No difficulty is expected in implementing a scanning system meeting the requirements dictated by the study program.

B. THE VIDEO PROCESSING SYSTEM

The heart of the proposed automatic target-recognition system will be the video processing system. Here, the thousands of data points defining the actual scene must be reduced to a much smaller group of measurements which efficiently describe the imagery. As pointed out in an earlier discussion, edge enhancement is one of the simpler forms of processing used on imagery; however, the transformation is one-to-one and does not reduce the total number of measurements that define the imagery. We have also said that a useful set of measurements would be minimally sensitive to translation and rotation; this, in fact, implies a nonlinear transformation of a many-to-one nature. That is, the image of an airplane, say, would yield the same set of measurements regardless of position or orientation on the scene.

The most promising form of processing thus far uncovered to minimize the effects of image translation and rotation relates to the integral scanning process described in the previous paragraph. If we imagine that the video signal is obtained as a long, narrow slit sweeps across some image, it is evident that the signal waveshape will be unchanged as the image is translated on the field. Let us further assume that our video signal is obtained by a sequence of integral scans in which the slit orientation is advanced through small angles between each scan until a complete circle is traversed. Under these conditions, the effect of image rotation is to shift the phase of the periodic sequence of video signals without changing the individual waveshapes. The net result of the sequence of integral scans is a video signal relatively insensitive to translation and rotation of the imagery.

The development of a video processor which can extract data from the integral scans has been the subject of the current research efforts. In principle, the techniques under investigation are similar; each attempts to establish a set of primitive waveshapes with which the incoming signals can be compared. The integral scan sequence provides a number of discrete video pulses (equal to the number of sample slits used) with which all primitive waveshapes can be compared. The resulting set of measurements can be used to provide a first-order description of the scene. By using a subsequent level of processing, we can take into account the time sequence of measurements obtained from each type of comparison; the time sequence will be periodic with a period equal to the time required for a complete circle of scans. This signal can be characterized independent of its phase, or equivalently, independent of rotation of the imagery. The primitive filters under study include bandpass filters which make measurements of spatial frequency, and tapped delay lines to implement weighting functions which can be used to measure correlation with arbitrary waveshapes.

Through the use of line integral scans and filters with arbitrary weighting functions operating on the video signals, the necessary two-dimensional integrals are implemented on the aerial scene. By neglecting certain phase characteristics in our measurements, the resulting parameters can be made essentially indifferent to translations and rotations of the imagery.

The video signals derived from point scans are not so easily processed for complex two-dimensional integrals. They can, however, be useful in deriving the characteristics of various isotropic density distributions such as those corresponding to wooded areas and other natural areas which are free of structure that has a preferred direction.

The specifications of the video processing portion of the automatic target recognition system will dictate the classes of two-dimensional weighting functions to be applied to the scene under process. The particular measurements represented by these integrals must efficiently describe the imagery, must permit the required separation of classes of interest, and must incorporate the types of many-to-one transformations of image data which minimize the effects of translation and rotation. Although explicit mention of other image variables such as aspect, illumination, seasonal changes, contrast and so forth has not been made, it is important that the scanner-processor combination maintain descriptive measures of the imagery in the presence of such changes.

The total number of measurements which the processor must generate and send to the adaptive recognition system will depend upon the signal-to-noise ratio expected on the incoming imagery. By signal-to-noise ratio in this context, we mean the ratio of signal from the object being sought to the total signal of the surround within the purview of the sample aperture. Noise can also be associated with unexpected structural variations in the object being sought which distort the set of measurements describing that object. The complexity of image description for signal and noise through various transformations permits only qualitative estimates of these values. Since overall system performance must also be based on the requirements of the recognition system, continuation of this discussion is deferred to the latter part of the next section.

C. THE ADAPTIVE RECOGNITION SYSTEM

The sets of measurements which define the various classes of imagery presented to the scanner-processor must be stored in a form appropriate for later comparison with test imagery; this is the role of the adaptive recognition system. It is a special-purpose computer which takes in sequence the sets of measurements on each class, compares them with previously received data, and modifies or adds to its memory the information on the new example.

The CONFLEX I, a general-purpose pattern-recognition system, was built nearly three years ago. New ideas have been introduced since that time, and the application of some of the concepts utilized in CONFLEX to a specific problem warrants the use of different processing techniques. For the reader who is not familiar with the existing CONFLEX system, a brief description has been included in an appendix.

The structure envisioned for the adaptive portion of the automatic target recognition system is similar to that of CONFLEX. The measurements from the processor will be combined in various ways in summing circuits and clipped to simple binary or ternary values by threshold circuits (D-cells). The most likely departures from the CONFLEX design will be in the manner of selecting the combinations of measurements prior to the clipping process, in the introduction of special processing of the bits forming the D-field as originally defined, and in the sequence of processing used during learning.

In CONFLEX, the combinations of inputs to the D-cell are selected arbitrarily; a pseudo-random number-generator sets switches in a cross-bar matrix to which the input signals are attached. As CONFLEX was designed for general-purpose pattern recognition functions, no a priori assumptions of the pattern structure were made. However, if we are given the structure of the preprocessing hardware and examples of typical imagery to be encountered in operation, the statistics of the measurements to be obtained can be estimated empirically. From these data, it is possible to design the sampling process to be in some sense optimized for the sets of measurements to be classified. For instance, a general rule regarding the information content of a set of measurements is based on the mean, variance, and covariance statistics over the range of inputs to be expected. If, over the gamut of possible input imagery, the measurements have strong covariance terms, then a sampling procedure may be selected which will minimize the effect of these terms. In the simplest case, this may be the removal of the DC term of unipolar measurements such as those associated with the density spectrum.

The details of the sampling process just described can be related to the manner in which the measurement space is initially partitioned. Since a D-cell output in its simplest form is a one or zero output according to the weighted sum of its inputs, the output tells us in which half of hyperspace the input pattern is located with respect to a hyperplane defined by the weighted sample. Prescribing the D-cell inputs can partition measurement space so that a uniform separation capability is obtained for the range of the expected inputs.

The special D-field processing prior to storage in the adaptive learning process can carry out two functions. The first of these is essentially a recoding of the partitions of measurement space established by the D-field. In the limit it is possible to assign one of a set of orthogonal codes to each possible D-field representation. This will make possible the arbitrary classification of a group of inputs provided only that distinct inputs produced distinct D-field responses. The drawback of such a system is that every expected partition must be preassigned its correct classification; this preassignment is similar to constructing an AND gate for every D-field and ORing the gates associated with the same class. By judiciously choosing the initial form of D-field processing, recognition of the various classes of imagery throughout reasonable ranges of variation and on the basis of small numbers of training examples can be achieved.

The second important process is the allocation of memory for statistical models which represent classes and subclasses of imagery. In practice, the D-fields for each of several classes of imagery will have common vector components. The rules by which a complete separating function are constructed must be formulated or adapted according to the characteristics of the problem. If one class of imagery is represented by sets of measurements with two distinct groupings or modes, the individual modes, in general, will each require a portion of memory for the statistical model. In a particular problem, however, the vector sum of these two modes may be distinct and nonambiguous, thus requiring a single vector representation in memory. It is evident that an ideal solution can not be reached until the complete set of examples has been examined. The purpose of the final stage of processing in the adaptive recognition system will be to recheck the criterion for class separation with the addition of each example. In this way, the system can adapt to classify patterns of measurements with both wide and narrow separation as long as the separations are within the partitioning of the D-field structure.

In the final analysis, we are concerned with the performance of the system in a real problem. Performance can be predicted when the statistics of the measurements are known for the classes of imagery to be recognized and for the noise or surround environment in which they must be found. We must finally arrive at the number of modes of input to be recognized, the variations to be expected and the resultant separation which can be achieved in the D-field representations. The first phase study program will be concerned in large measure with the accumulation of empirical data on which design parameter and performance characteristic data can be based.

D. STATUS OF CURRENT INVESTIGATIONS

Under recently completed and current contracts, [redacted] 25X1
25X1 [redacted] has studied two facets of image processing, the line integral scan (formerly termed "conical transform") and the effects of image variability on recognition.

The line integral scan was studied under Air Force contracts
25X1 [redacted] Under contract
25X1 [redacted] recently completed, program effort was directed toward effecting preliminary evaluations of the integral scan, bandpass-filter form of processing system. In these experiments, 30 sets of prenormalized data that represented TITAN site imagery were used. Although the crude breadboard constructed during the first study program was used in taking the experimental data, the experiments produced encouraging results. Correct identifications were made of all the training examples presented to the CONFLEX system and of 87 percent of the unknowns.*

Under a current Air Force contract, [redacted] is continuing 25X1
experimentation related to the line integral scan. Ten tapped delay line filters for measuring the integral scan signatures have been constructed. The hardware has just been completed and will soon provide valuable information regarding the processing capabilities of the filters. Each filter is equipped with variable threshold gates and gated counters to tally the statistics of the resulting measurements.

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* Including unknowns at orientations different from those used in training.

The other facet of image processing, the effects of image variables which affect recognition, is being considered under a CONFLEX study program [redacted]. We 25X1 have, through controlled experiments, tested the effects of the following variables in addition to the variables of translation and rotation:

1. Scale
2. Background Noise
3. Aspect Angle
4. Illumination Angle
5. Image Contrast
6. Background Contrast
7. Resolution

The recognition performance characteristics of the CONFLEX system were tested with each variable under independent control. Over 400 examples of each test scene were prepared for use in this program. In general, the results demonstrated that translation and rotation have the strongest detrimental effect on system performance. In these experiments, the CONFLEX was tested with the imagery directly. We expect the prenormalized data to be even less sensitive to some of these variables, but the experimental work has yet to be carried out. Part of this work will be executed under the current sponsor program. It is expected that further testing will be required in the proposed program to establish and evaluate the operational system specifications.

Under the current sponsor program, the large scale pre-normalizing system has just been assembled. During the preliminary phases of this design, our confidence in the proposed scheme was reaffirmed by the use of simple modeling procedures using computer simulation. The system, as it now stands, will execute 51 integral scans on the viewed area and generate 400 prenormalized variables which interface with the CONFLEX I through an electronic sensory field. Testing of the system will include some of the image variable work just described which progresses from simple simulated imagery to very low signal-to-noise target detection tests. Thus far in the program, the principal gains have been experienced along hardware lines, especially that for implementing the scanner processor system. At least three months of testing will be conducted which will give broad insight into the performance of the prenormalized variables.

In each of the programs described above, an independent study effort has been made with the inclusion of experimental tests. The important study phase of the proposed program will be used to combine and extend this work.

E. SUMMARY

The major factors to be considered in the design and development of an automatic target recognition system have been briefly discussed in this technical proposal. The basic elements of the system include the optical scanner for transducing data from the input film, the video processor for reducing the number of measurements to be processed, and the adaptive recognition system.

The scanner-processor portion of the system will be two physically separate units with the joint functions of transducing data from the input film and providing the set of measurements which describe the imagery. The principal design considerations have to do with the exact form of the aperture or apertures which scan the film image and with the types of filters used to combine picture elements for purposes of making the measurements.

The first or study phase of the proposed program will be concerned with the utility of available techniques and with selecting suitable ones. During the second phase, the design and construction of the operational system will be carried out, using off-the-shelf hardware components, insofar as it is possible.

III. PROPOSED PROGRAM

The goal of this program is to develop a prototype of an operational, automatic target-recognition system. The proposed system will automatically process all standard width films, and the system's output will include the frame (and location thereon) in which classes of interest are found. The system will have the capacity to search on 10 classes, simultaneously, and the classes will be easily and quickly programmable.

We believe that a successful program to develop an operational target-recognition prototype must include a thorough study of current image-analysis technology. For this reason, the proposed program is divided into two distinct phases. The first phase (which will consist of research, evaluation, experimentation, and establishment of preliminary design) will be conducted to fix the design parameters and verify the associated performance characteristics. The second phase will be devoted to the design, construction, and testing of the prototype system. Further details are given in the following paragraphs.

A two-year program to execute the entire development effort is contemplated. The timetable for the tasks described below is given at the end of this section.

PHASE I - NINE MONTHS

The nine-month study phase will be divided into five tasks that will be carried out partly in series and partly in parallel. These areas can be termed (1) research, (2) experimentation, (3) technique evaluation, (4) preliminary design, and (5) theoretical system evaluation.

Task 1

The first task will be to collect detailed information on current work pertinent to the automatic target recognition problem so that the overall design decision can be made with full knowledge of all available techniques. The principal objects of study will be the transformation(s) implemented by the scanner-processor and the various organizations of adaptive learning systems. In the case of the scanner-processor combination, attention will be given to the classes of two-dimensional integrals afforded by various systems. Point and aperture scans will both be considered in the light of various processing schemes. Strong consideration will be given to the line integral scan being tested under a current sponsor program. A rotating TV-type scan used in investigations by Litton also represents a means of sampling the aerial scene in a manner which lends itself to meaningful types of processing. The subsequent filtering and detection techniques which will be considered are the bandpass filter scheme under current study, time domain filtering using tapped delay lines, and other easily implemented descriptors such as those under investigation by other research groups.

The structure of the adaptive recognition system will be based on the CONFLEX system and on recent innovations that deal with problems not solvable by normal linear separation techniques. A principal research task in this area is the generation of algorithms for creating subclasses to handle multimodal class distributions. These may be necessary when objects of the same class are represented by sets of measurements which occupy separate and disjunct regions of the decision space. General classes of vehicles, light manufacturing areas, ships, and aircraft are among those which can have distinct subclass categories.

Finally, under Task 1, we will, in collaboration with the sponsor, investigate the classes of imagery of interest and select those most pertinent to operational objectives. We anticipate that the usual strategic classes of imagery will be of interest, including airfields, industrial or urban areas, missile sites, radar complexes, tank farms, shipyards and areas involved in light manufacturing. Under the tactical class of imagery will fall tanks, artillery emplacements, troop emplacements, trains, vehicles and ships at sea. We recognize the importance of having special classes which can be rapidly adapted to any arbitrary object or complex feature of interest, and this capability will be included in the system design.

In summary, the first task will consist of compiling the available techniques and operational objectives, selecting those techniques which hold promise in application to the system, and ferreting out special problem areas or gaps which need attention. Also, the classes of imagery to be treated will be examined.

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Task 2

Task 2 will consist of using available scanner and prenormalizing equipment and a general-purpose computer to gather empirical data on typical types of imagery. This data will be used to produce the statistical data necessary for the evaluation of specific scanner-processor systems.

Requirements for additional hardware during this study phase will be limited to some digital recording equipment for rapid data acquisition from the existing prenormalizer and scanner. The general-purpose computer will be used: (1) to simulate the algorithms for learning set forth in the first task, (2) to generate statistical data on prenormalized measurements, (3) to develop performance characteristics, and (4) to simulate any other system processes deemed reasonable in the research program.

This task will have as its goals the testing of the transformations implemented by the prenormalizer-processor combination and the performance of various adaptive learning structures.

Task 3

During and after completion of the experimental work, an evaluation will be made to determine the exact forms of scanning, processing, and learning procedures to be used. This evaluation will be based, in part, on the empirical data obtained during the latter phases of our current programs, partly on our experimental work in the proposed program, partly on the experimental work of others, and partly on the results of theoretical considerations. Regarding the prenormalized measurements, the statistical analysis will permit an evaluation of their efficiency both in characterizing the imagery and permitting discrimination of the various classes.

In all evaluations, both the theoretical and practical aspects of implementing the available methods will be compared with the performance data. We believe that our previous experience in building scanners, analog processors, and adaptive learning systems will insure that our choice of methods will have excellent implementation potential.

Task 4

On the basis of the methods evaluation, a preliminary design of the entire system will be prepared. At this time, the scanning method and the forms of processing to be used will be chosen. Also, the character and number of measures required to achieve a specific level of performance will be specified.

At the end of this task, the block diagram and functional specification for the system will be completed. These will include the necessary system parameters such as optical resolution, video signal-to-noise ratio, bandwidth characteristics, number of measurements, adaptive system capacity, etc.

Task 5

Task 5 will consist of the preparation of performance characteristics which will be obtained with the system design. All empirical and theoretical measures of performance will be drawn upon to provide a fair estimate of the system performance. All trade-offs between time and hardware or performance and system complexity tentatively set in previous tasks can be finally established at this time.

Task 5 will conclude the work in Phase I. The results of this work will be fully documented, in the form of an interim technical report, at the end of this nine-month period.

The main result of Phase I will be a complete system specification and a functional design of the system to serve as the basis for detailed system design and development. The specification and functional design will represent the inte-
25X1 grated results of [redacted] efforts in automatic processing and the efforts of other research groups involved in this area of investigation.

ANTICIPATED DESIGN PARAMETERS

Because a study has not yet been made of the desired operational system, the critical design parameters can only be estimated at this time; however, a reasonable judgment based on previous experience places some very tentative requirements on the operational system. We envision a scanner with a scanned area variable between 0.1 and 1.0 inches at the film, with approximately three to five hundred line resolution on the area within the purview of the scanner. Approximately five hundred well-defined measurements on the scene under process should be adequate to achieve probability of detection of approximately 0.9 with a false alarm probability under .01 for a ten class search. Provisions will be made for approximately ten modes of subclass storage for each class. The processing speed will be approximately one linear inch of film per second, and video bandwidths on the order of two megacycles will provide this system speed. Servo speed control may be necessary to accommodate varying film densities and widths. A small printer will type the output classifications, associated film position, and the confidence level of the decision. We must repeat that these estimates are tentative and cannot be determined accurately before the system study; they are meant only to convey our present best estimate of these parameters.

PHASE II - FIFTEEN MONTHS

The detailed design, construction, and testing of the operational prototype system will be carried out in a fifteen-month program. Five specific tasks must be carried out in serial fashion. These tasks include (1) detailed system design, (2) fabrication and assembly, (3) debug, (4) testing, and (5) documentation.

Task 1

The detailed design of the system will be made, using the preliminary design data developed during the study phase. The design will use commercially available components to the fullest extent. Unnecessary hardware development will be kept to a strict minimum.

Task 2

The necessary parts procurement and shop fabrication will be undertaken as soon as the final design has been determined in Task 1. The assembly and wiring of the system will be completed under Task 2.

Task 3

A complete checkout of optical and electronic systems will be made under Task 3. All processing steps will be checked to make sure that they function as intended in the final design.

Task 4

During Task 4, the system capabilities will be checked out, using test aerial imagery. Experimental imagery having a wide range of variation will be tested to determine the range over which satisfactory performance can be expected.

Task 5

The results of the program will be brought together in a final report prepared at the end of the two-year interval. The emphasis at this time will be on reporting the details of the system performance and on making recommendations regarding operational use of the system.

TIME SCHEDULES

Figure 3 is a timetable for execution of the separate tasks in the two-year program. Slight adjustments may be necessary in the future to accommodate variations in the anticipated timing. The entire program will be PERT monitored to assure an efficient and coordinated execution of the tasks.

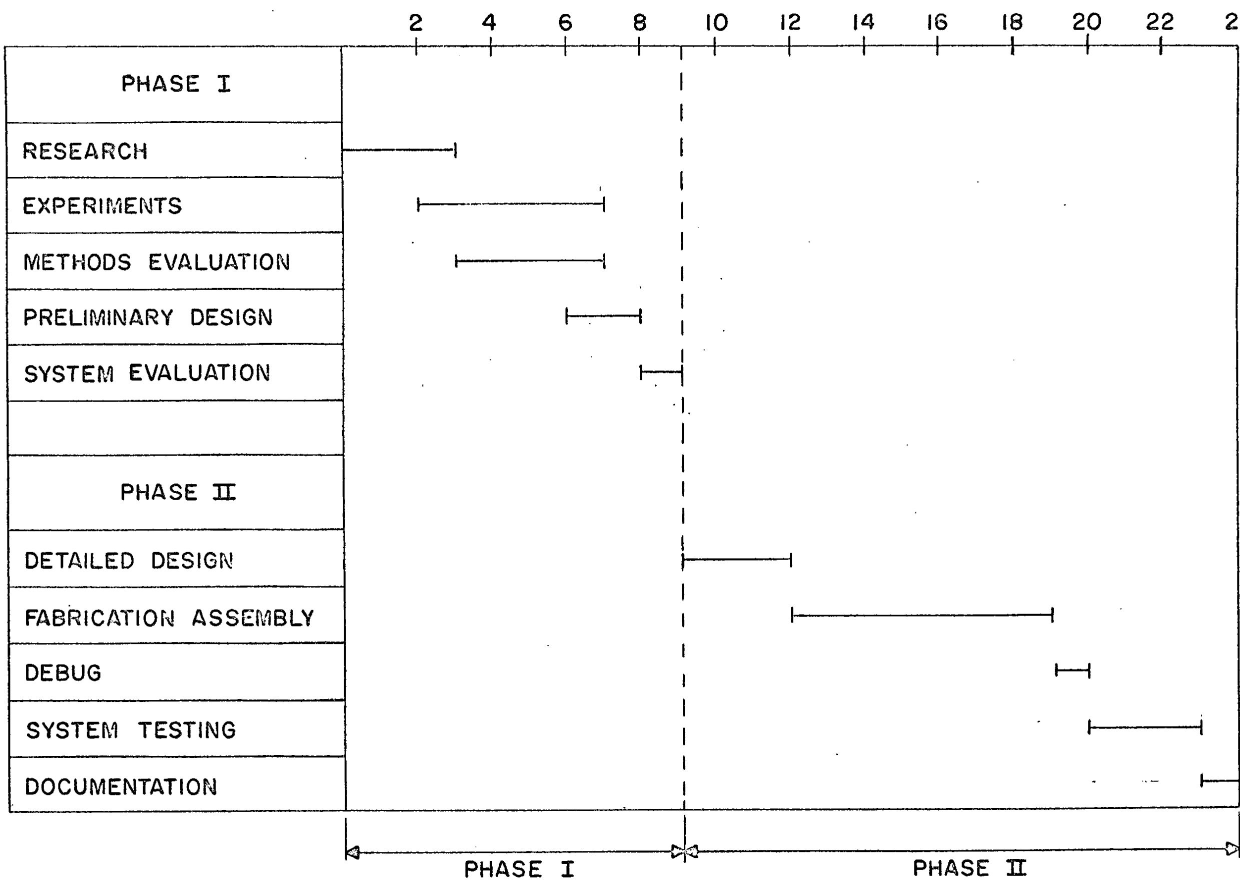

FIGURE 3
PROPOSED TIMETABLE
DEVELOPMENT OF AN AUTOMATIC TARGET RECOGNITION SYSTEM

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IV. PROGRAM PERSONNEL

TECHNICAL TEAM

Specialized engineering teams at [redacted] have developed, through long-term collaboration on numerous research and development programs, an unusual capacity for cooperative team effort. This capability is especially valuable on quick-reaction programs, as is indicated by [redacted] corporate history of strict adherence to contracted schedules. 25X1 25X1

[redacted] 25X1 has an exceptionally low rate of personnel turnover and, once a technical team is selected, the customer can be assured of a reasonably firm personnel commitment.

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APPENDIX A

TECHNICAL BIOGRAPHIES

Next 8 Page(s) In Document Exempt

APPENDIX B

PRODUCTION CAPABILITIES AND FACILITIES

25X1

[redacted] PRODUCTION CAPABILITIES AND FACILITIES

25X1 [redacted] fabricates hardware for a variety of applications, including laboratory breadboard models as well as rugged equipment designed to meet severe environmental conditions. Microwave work, ranging from the small filter cavity to large antennas, is our specialty.

25X1 [redacted] production facility occupies 10,000 square feet. The facility consists of four discrete sections: the Machine Shop, the Wiring Shop, the Photo Laboratory, and the Quality Control Department. The company maintains all of the test equipment necessary to conduct government-specified test procedures, including audio, VHF and UHF testing, as well as a 50-foot antenna test range. Each section in the production facility is excellently equipped to meet delivery schedules with a normal safety margin.

WELDING AND SOLDERING CERTIFICATION

25X1 [redacted] shop employees are thoroughly indoctrinated in the specifications governing the fabrication of military electronic chassis and components. Our shop foreman, [redacted] 25X1 attended and is a certified graduate of the National Aeronautics and Space Administration's Welding and Soldering Instructors' Course at Huntsville, Alabama. All of our electronics technicians and assemblers have completed the two-week certification course that he conducts at [redacted] and they 25X1 are certified to do welding and soldering in accordance with MSFC Proc. 158B.

This certification is mandatory for all contractor personnel doing fabrication for NASA; consequently, [redacted] also conducts classes at NASA's Goddard Space Flight Center for the personnel of other contractors at GSFC. These classes are sponsored by the participating contractors with NASA approval and encouragement. 25X1

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I. MACHINE SHOP

25X1 [redacted] Machine Shop performs welding, sheetmetal, and assembly work, as well as machining. Shop capabilities include a variety of highly complex setup and operational tasks on any machine tool or accessory, or on any sheetmetal working tool or accessory.

MACHINING

Machining (turning, milling, grinding, drilling, and boring) of both metals and plastics is done to specified dimensions, planes, or angles. [redacted] does machine work to tole- 25X1
rances that range from a fairly exacting (±0.005 inches) to an extremely exacting (±0.0002 inches) precision, with minimum finishes ranging from 63 to 8 microinches.

SHEETMETAL OPERATIONS

Sheetmetal work (shearing, forming, notching, punching, and drilling) is done on ferrous and nonferrous metals, when most of the parts in the assembly or detail are one-eighth inch thick or less, to minimum tolerances. [redacted] sheetmetal 25X1
operations include general sheet layout and handwork for the production of intricate assemblies, and require a high degree of manual dexterity.

WELDING

Arc welding, including heliarc (certified), inert-gas, and tungsten-arc welding, is performed on ferrous and non-
25X1 ferrous materials at [redacted] with dimensions held to exacting tolerances. Brazing and silver soldering are also available.

FINISHING

25X1 [redacted] applies chemical, organic, and metal finishes to various ferrous and nonferrous materials. Organic finishes are applied by brush and spray, and are both air dried and baked dry. Metal finishes, in compliance with MIL specifications, include magnesium conversion coating (6 x 6 x 6 inches, Dow 7 and 9), aluminum conversion coating (etch or nonetch cleaner, 24 x 24 x 24 inches), and silver plating (immersion) for copper and copper alloys (6 x 6 x 6 inches).

ASSEMBLY

Quantities of complex electromechanical equipment, such as flush-circuit switching, commutator-brush assemblies, and continuous belt-driven, photoelectric, tone-generating disc
25X1 units, are assembled in [redacted] Machine Shop.

The remaining pages in Part 1 contain photographs of our Machine Shop and of typical products fabricated there.

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II. WIRING SHOP

25X1 [redacted] Wiring Shop, fully experienced in the wiring of electronic and electromechanical assemblies and subassemblies, specializes in rugged, subminiature circuit modules. Routine tasks include the wiring of special-purpose computers and data-processing systems designed and constructed at [redacted] Other 25X1 Wiring Shop functions include the assembly of harnessing and cables, and encapsulating. The Shop is equipped with such special facilities as ovens, inert-gas chambers, special vacuum chambers, and pressurized encapsulant guns.

ENCAPSULATING AND BONDING

Our technicians are especially experienced in applying resin encapsulants, foams, and conformal coatings to protect equipment against stringent environmental conditions. Common materials used for this purpose are Ecco-foam, sty-cast, Scotch-cast, RTV silastic, and polyurethane. The capabilities of this Shop also include the bonding techniques, encompassing adhesive bonds such as glass-to-metal and teflon-to-most materials.

PAINTING

Refined mechanical cleaning and chemical cleaning are effected by liquid honing and vapor degreasing, respectively. After preparation by these cleaning and surface treatment, small components are routinely painted in-house to military specifications.

III. PHOTO LABORATORY

25X1 [redacted] Photo Laboratory is equipped to process all types of black-and-white film and to make 16 x 20 inch contact prints. The Photo Lab also processes and reproduces art work for circuit boards and for tone generator discs and nameplates, and prepares stencils for silk-screening. Advanced techniques of controlling the exposure of Ektachrome film have 25X1 been achieved at [redacted] during the past two years.

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IV. QUALITY CONTROL DEPARTMENT

The Quality Control Department at [redacted] is responsible for insuring that [redacted] products comply with the customer's specifications. The manager of this department reports directly to the Executive Vice President. Our rigid quality control system is actively enforced and is approved as meeting the requirements of MIL-Q-9858 by the Cognizant Government Inspection Agency, INSMAT, Baltimore, Maryland. [redacted] Quality Control is further certified by Lockheed Missiles and Space Company and General Electric Company.

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Specific procedures for accomplishing the requirements of MIL-Q-9858 are set forth in [redacted] Quality Assurance Manual. These procedures provide for incoming and in-process inspections; calibration of test equipment, tools, and gauges; handling of defective material; vendor surveillance; and for the shipping, receiving, and handling of materials. In-house workmanship standards are established by the Engineering Standards Manual and are controlled by Quality Control inspections and tests.

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Inspection and test parameters are determined from the contract specifications and task statement, and in-process inspections are performed to assure conformance. Non-conforming parts discovered during inspection are reviewed by Engineering Shop Services and Quality Control. Corrective action is then taken to eliminate recurring discrepancies. Drafting room

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procedures strictly dictate that all manufacturing, production, and engineering changes be incorporated into the basic drawings and require prompt distribution of changes to all activities concerned.

Quality Control also maintains liaison with both vendors and customers in order to direct the quality-control effort in such a manner that a quality product will be delivered at an economical cost.

25X1 [redacted] has an extensive inventory of standard test equipment, including oscilloscopes, signal generators, and voltmeters.

The fifty-foot antenna radiation pattern test range maintained by [redacted] has the capability of measuring radiation patterns over a 30 db dynamic range. In addition, [redacted] has the capacity to completely design and test antenna voltage standing wave ratio (VSWR), and to conduct Government-specified test procedures, including audio, VHF and UHF areas.

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25X1

RESEARCH & DEVELOPMENT
IN THE PHYSICAL SCIENCES

19 March 1965

[redacted]

25X1 Subject: [redacted] TP-288, Development of an Automatic Target Recognition System

Gentlemen:

25X1 [redacted] is pleased to submit the attached technical proposal for your consideration. Also attached is our cost proposal for the complete program. The work described in our technical proposal represents a logical succession to the work presently being brought to conclusion under a current program with the Sponsor.

The total program described in our technical proposal involves a technical effort of 24 months. This effort is divided into two phases. Phase I covers a study effort of nine (9) months and Phase II covers the design and construction of the prototype system. The total estimated cost for the entire program
25X1 is [redacted] and is bid on a CPFF basis. The bid is valid for ninety (90) days from date of this letter. The total cost for the program has been broken down into Phase I and Phase II as indicated on the attached Cost Analysis Sheets.

We look forward to your review of our proposal and invite any questions or discussion you may have concerning it. If you have questions concerning technical aspects of the program, please call [redacted] 25X1
Falls Church, Virginia. Questions concerning contractual matters should be addressed to [redacted] at the same number. 25X1

Sincerely,

[redacted] 25X1

Director, Marketing and Contracts

VB:HLF:ms
Encls: Cost Analysis Sheets, 5 cys.
Technical Proposal, TP-288, 5 cys.